Fingerprints On Counterfeit Currency

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ABSTRACT

A number of techniques, including 5-methoxyninhydrin/$ZnCl_2$, DFO, DMAC, physical developer, colloidal gold, membrane transfer and vapor development , have been explored in an attempt to distinguish between fingerprints on counterfeit currency before and after the inking. Color copying and offset printing counterfeiting were considered. The printing ink proves to be too permeable to permit ready distinction between "before" and "after" fingerprints. There are subtle differences between before and after fingerprint fluorescence spectra (5-methoxyninhydrin/$ZnCl_2$). However, given that one has to contend with finger contamination, the spectroscopy is at present not practically useful, but it shows potential if the fingerprint fluorescence spectrum can be correlated quantitatively with the ink absorption spectrum. Time-resolved spectroscopy in concert with rare-earth-based fingerprint development strategies may be useful as well.

Keywords: counterfeit currency, fingerprints, lasers, 5-methoxyninhydrin, $ZnCl_2$, DFO, DMAC, Physical Developer, colloidal gold, transfer membranes.

INTRODUCTION

The counterfeiting of currency keeps increasing every year. $20 million in counterfeit bills was passed in the U.S. in 1993, $25 million in 1994 and $15 million at the halfway point in 1995[1]. The main reason for the increase may be the appearance of advanced color copiers, computer scanners and color printers.

Whether one can identify the counterfeiter from fingerprints on the counterfeit notes depends on whether the fingerprints were placed on the paper before the printing ink (FB, see Fig. 1a) or after (FA, see Fig. 1b). If the fingerprint was placed on the counterfeit

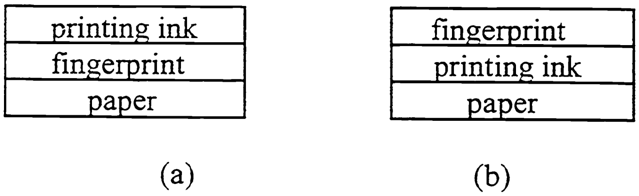

Fig. 1. (a) Fingerprint Before the Printing Ink (FB)
(b) Fingerprint After the Printing Ink (FA)

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note before the printing step, the corresponding person must be the counterfeiter. If the fingerprint was placed on the counterfeit note after the printing step, the corresponding person can still be the counterfeiter but not necessarily. Thus, a method is needed to detect the latent fingerprints, and, at the same time, to distinguish between FB and FA. Ideally, after a chemical treatment, the fingerprints on the ink area can be seen clearly for the FA case but cannot be seen for the FB case. Another prospect is that the fingerprints in two cases show a relative difference in the change from the "white" area to the "ink" area if the fingerprint covers "ink" and "no ink" areas. For example, the clearness or fluorescence intensity (under laser excitation) of the fingerprints show dramatic change in one case but not in the other case. Above all, the method must have the capability to show a substantial difference between the two cases in order to have probative value.

MATERIALS, METHODS AND RESULTS

Fingerprints are composed of salts, amino acids, lipids, vitamins etc., after the water evaporates. The methods of fingerprint development on paper usually concentrate on detecting amino acids or lipids, mostly the former. The current method of detecting fingerprints on paper with lasers can be divided into two main steps. In the first step, the fingerprint is treated with a chemical which reacts with amino acids in fingerprint residue to form a fluorescence product. The second step is conducted in a dark room. The treated fingerprint is illuminated by laser and observed through a filter which rejects the reflected laser light but transmits the fingerprint fluorescence. The fluorescent fingerprint is then photographed or recorded by a video camera[2].

Sample preparation

Different color strips are printed (both copy and offset printing) on to both copy paper and bond paper (see Fig. 2). The strip is about one centimeter in width. Fingerprints or glycine (an amino acid) spots, are put on paper both before and after the printing step. We started with deep green and black inks which match the colors of U.S. currency notes. It is difficult to develop fingerprints on the black or the deep green ink area.

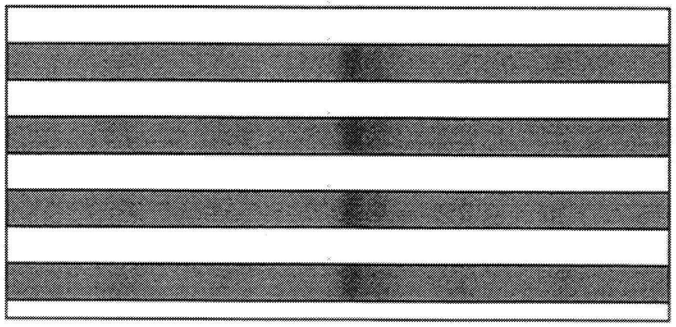

Fig. 2

PD (Physics Developer) and Colloidal Gold, which turn the fingerprint into a gray mark, will provide poor contrast. Accordingly, we also prepared blue and yellow ink samples in order to understand the problem better. The reason to use glycine spots is that the amount of amino acids in fingerprint residue can vary substantially from person to person. In order to get more reproducible results, we used the glycine spots to stand for the fingerprints for some of our samples. The glycine solution is prepared by dissolving glycine in methanol.

Chemical fingerprint treatments

The fingerprint treatments utilized for the development of fingerprints were either standard procedures used by fingerprint examiners or procedures that have been published in the literature, even if they are as yet not routinely used. They are enumerated below:

- 5-methoxyninhydrin (2,2-dihydroxy-5-methoxy-1,3-indanedione): reacts with amino acids in fingerprint residue to produce Ruhemann's Purple.

- $ZnCl_2$: reacts with Ruhemann's Purple to produce orange fluorescence under Ar laser excitation[3].

- $EuCl_2$: reacts with Ruhemann's Purple to produce red fluorescence under UV excitation. Even though the fluorescence is not as strong as that of the Zinc complex, it has a long life time (about 0.5 ms) and thus has the potential to be used with time-resolved imaging[4].

- DFO (1,8-diaza-9-fluorenone): reacts with amino acid in fingerprint residue to produce orange fluorescence under Ar laser excitation. DFO is considered to be one of the best reagents for fluorescent detection of fingerprints[5].

- DMAC (Dimethylaminocinnamaldehyde): reacts with fingerprint residue to produce yellow fluorescence under Ar laser excitation. DMAC can be used for fuming to develop fingerprints[6].

- PD(Physical Developer): reacts with lipids in fingerprint residue to form gray fingerprint ridges.

- Colloidal Gold: This is a modified PD procedure. Colloidal Gold can also be used for transferring fingerprint from paper to membranes[7].

The 5-methoxyninhydrin/$ZnCl_2$ treatment was used instead of the standard ninhydrin/$ZnCl_2$ procedure because of its higher fluorescence yield. Since polar solvents readily wet paper, the amino acid reagent approaches were supplemented by lipid-sensitive approaches (PD, colloidal gold, dichlorofluorescein), and membrane transfer procedures. All of these procedures are basically wet, and, given the permeability of the printing ink on the paper, were expected to be potentially deleterious to FB, FA fingerprint distinguishability. Accordingly, two vapor procedures (DMAC fuming, 9-methylanthracene +coumarin 535) were also explored. Finally, erasing fingerprints was attempted (by pencil eraser or knife blade) with the idea that FA fingerprints would be obliterated but not FB fingerprints (in the ink area).

The methods and the results are summarized in the following table:

	Materials and Methods	Results
1	5-methoxyninhydrin + $ZnCl_2$ The sample is dipped into (or sprayed by) 5-methoxyninhydrin first, and after the prints turn purple, dipped into (or sprayed by) $ZnCl_2$.	When used on the glycine spots it produces strong fluorescence for both FB and FA; when used on fingerprints the fluorescence is not strong enough in the deep green (or black) ink area for both FB and FA samples. For the blue ink samples, the fingerprints can be seen clearly in both cases.
2	5-methoxyninhydrin + $EuCl_3$ (or $Eu(NO_3)_3$) Same as above.	Basically the same as above, but the fluorescence is weaker. The sample is excited by UV lamp.
3	Physical Developer Standard method.	Since the color of the product of the PD + fingerprints is gray, the fingerprints cannot be seen clearly in the green (or black) ink area. For the blue ink or yellow ink, the fingerprints can be seen in both cases.
4	Colloidal gold Standard method.	Similar to above.
5	Colloidal gold + membranes Standard method.	Among all the investigated membranes only the Immobilon-P and the Immobilon-NC transfer membranes work for some kinds of paper. For the bond paper the transferred fingerprints can barely be seen. For the copy paper the result is worse.
6	DFO The sample is dipped into the DFO solution.	Can produce strong fluorescence for both FB and FA fingerprints on the ink area.

	Materials and Methods	Results
7	DFO Before dipping into the DFO, the fingerprints on the ink area for both FB and FA are erased with a pencil eraser first or scratched with a knife.	Same as 6. The results indicate that the ink does not stop the amino acid of the fingerprint residue from passing into paper.
8	DMAC The filter paper is dipped into the DMAC solution. After drying, filter paper is put on the sample and steam ironed.	The fluorescence is not strong enough to be seen in the green (or black) ink area in both cases.
9	DFO As 8, but the iron is filled with acetic acid instead of water.	Similar to 8.
10	DMAC Fuming.	The fingerprints look essentially the same in both FB and FA on blue ink areas.
11	2',7'-dichlorofluorescein[8] The fingerprint on the ink area is erased first and then the sample is dipped into the solution.	The fluorescence is not strong enough in the green (or black) ink area in both cases.
12	5-methoxy-ninhydrin + $ZnCl_2$ Comparing the fluorescence intensity of the fingerprints between white area and ink area by scanning across both areas in both cases.	Does not give useful information.
13	9-methylanthracene + coumarin 535[9] Fuming.	The result is similar to 10 but the fluorescence is weaker mainly because the excitation source is a UV lamp.
14	Semi-dry electrophoresis device + membrane Standard method	This method aims at transferring the polar components of fingerprint residue from the paper to the membrane but nothing is seen on the membrane except the ink.
15	5-methoxy-ninhydrin + $ZnCl_2$ Emission spectrum in printing ink area	After normalization, there is a small difference between the FB and FA cases. See text.

DISCUSSION

The printing ink is too permeable to play a role of separator. The reason for not being able to distinguish between FB and FA is due to two possibilities. (a) The fingerprint residue can pass through the printing ink when a finger is pressed against the ink surface for the FA case. This will make the FA almost the same as FB. (b) During the process of the fingerprint development, the solution carries most of the fingerprint residue or the formed product through the printing ink because the current methods of developing fingerprint on paper are basically "wet" methods. If this is the case, there is still a possibility for the problem to be solved if a more sensitive "dry" method of detecting fingerprints on paper is developed. Our results with membrane transfer, fuming and erasure procedures, however, suggest that that the ink permeability is the main problem. A further complication arises from paper background fluorescence. Financial and time constraints precluded the exploration of time-resolved fingerprint imaging in the counterfeiting context. To eliminate the background problem, this is an area worth further work. Also a greater range of excitation wavelengths could be useful. We are currently investigating the utility of UV capable Ar lasers.

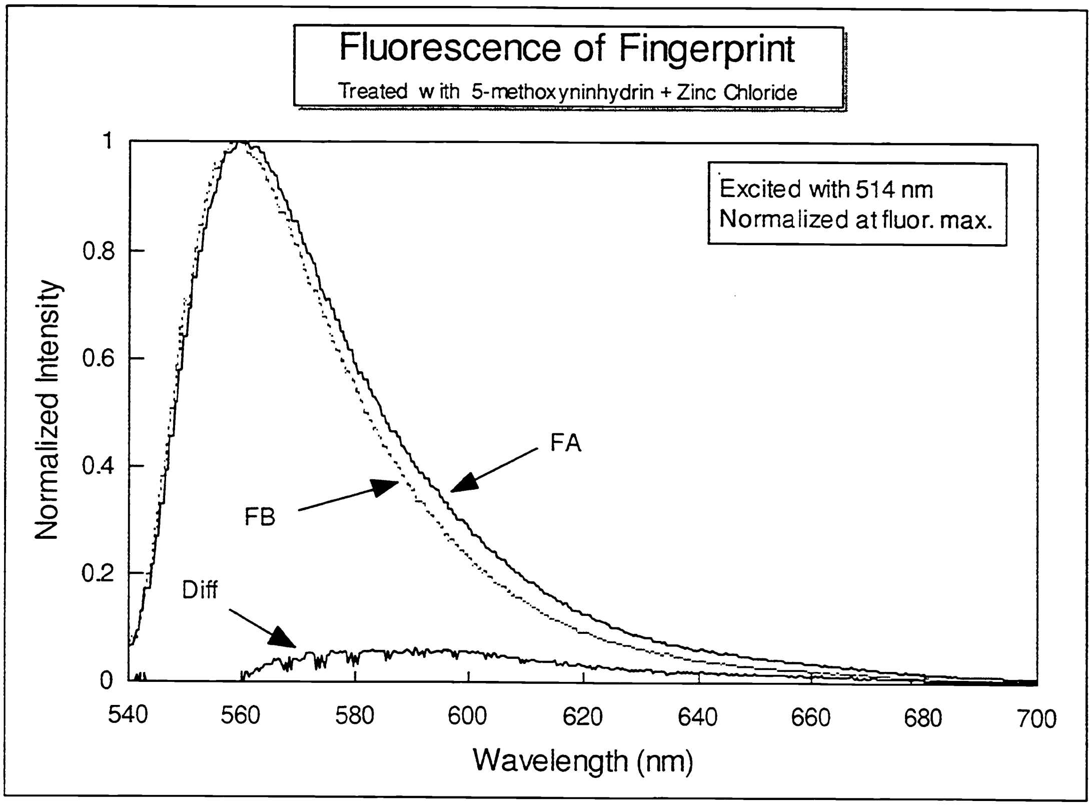

Fig. 3

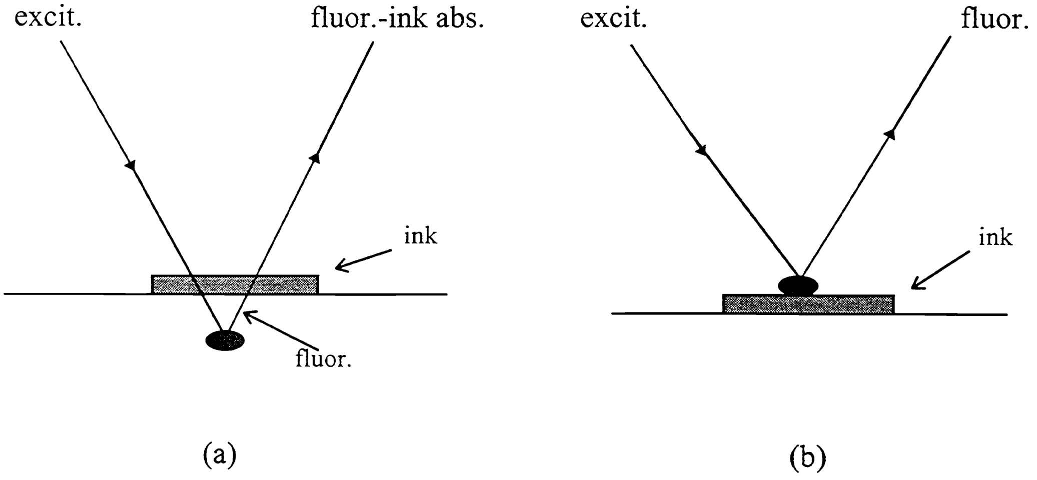

Fig. 4

We attribute the differences in FA and FB fingerprint spectra (see Fig. 3) to fluorescence absorption by the (blue) printing ink, as depicted in Fig. 4. Complicating features here are the reflectivity of the ink and paper background fluorescence. Again, rare earth-based fingerprint development strategies in concert with time-resolved spectroscopy may be of help here, especially since fluorescent fingerprint contamination can be disposed of. Instead of normalizing the fluorescence at its maximum, it may be normalized at a different wavelength to enhance the difference between FA and FB fingerprints, as shown in Fig. 5 and 6. The spectral cross-over in Fig. 6 makes the FA vs. FB case particularly obvious. The FA-FB spectral difference is in keeping with the (blue) ink absorption.

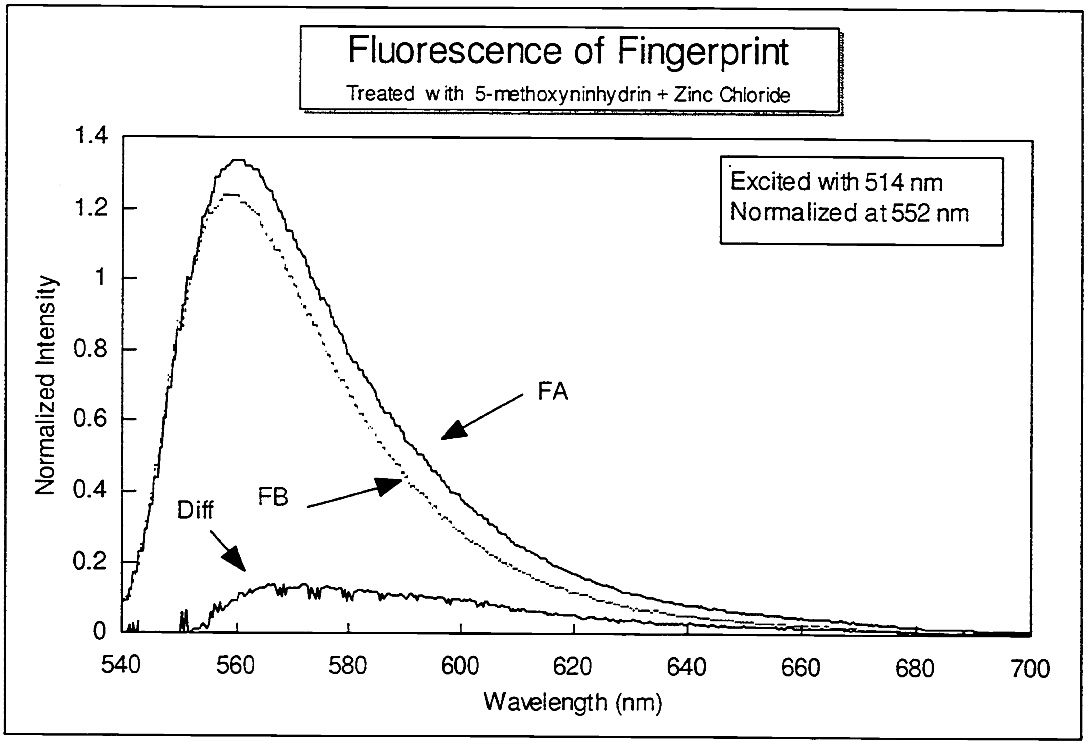
Fluorescence of Fingerprint
Treated with 5-methoxyninhydrin + Zinc Chloride
Excited with 514 nm
Normalized at 552 nm
Normalized Intensity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Wavelength (nm)
540
560
580
600
620
640
660
680
700
FA
FB
Diff

Fig. 5

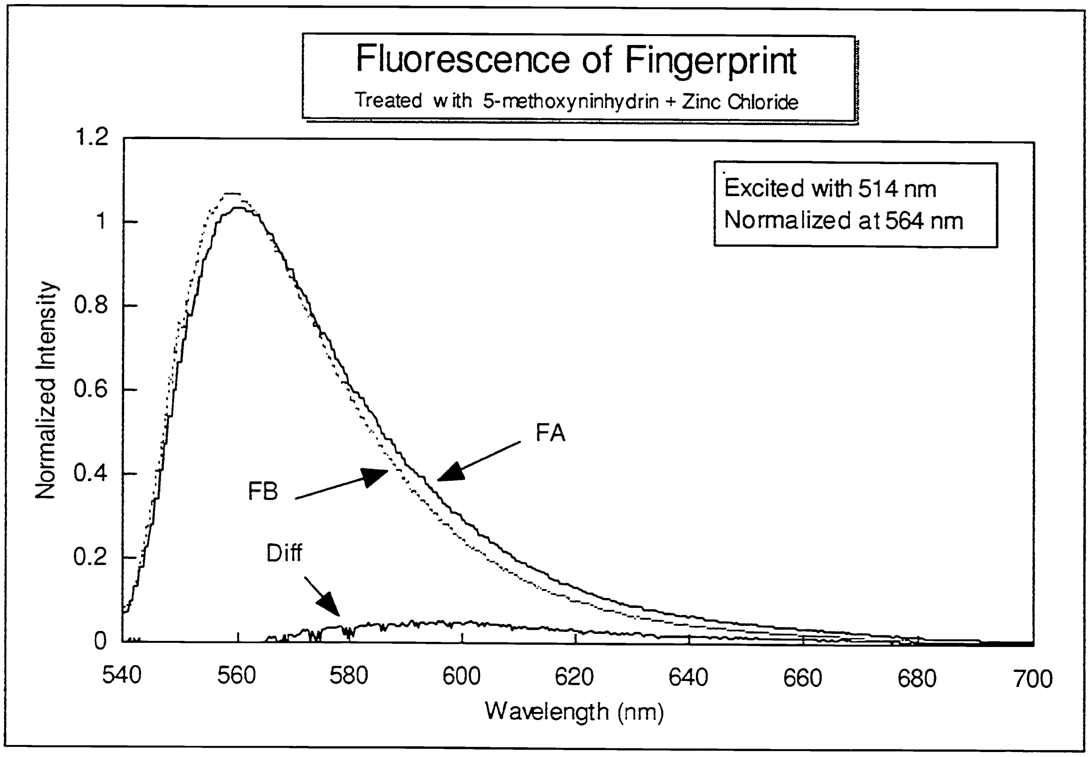
Fluorescence of Fingerprint
Treated with 5-methoxyninhydrin + Zinc Chloride
Excited with 514 nm
Normalized at 564 nm
Normalized Intensity
0
0.2
0.4
0.6
0.8
1
1.2
Wavelength (nm)
540
560
580
600
620
640
660
680
700
FA
FB
Diff

Fig. 6

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